10 Mapping Complexity

As we explained in our review of complexity science (Chap. 5), given the challenges of modeling complex systems, scholars in this new of field of study (particularly those working to advance agent-based modeling and the new science of networks) have developed a rather significant list of visual techniques. The purpose of these visual techniques is to help researchers and readers grasp what are otherwise difficult issues to explain verbally. Said another way, complexity scientists take the viewpoint that *a picture of a complex system is worth a thousand words*.

The SACS Toolkit adheres to the same viewpoint. As explained in Chaps. 2 and 3, the SACS Toolkit is highly visual, relying upon a rather extensive repertoire of techniques taken from social network analysis, the new science of networks, social simulation, fractal geometry, cluster analysis, grounded theory, and the self-organizing map literature.

Integrating these techniques, the SACS Toolkit provides a novel approach to visualizing social systems. In this chapter (and throughout the book) we provide readers a viewfinder into this novel approach. In addition, all of the maps, figures and graphs in our book can be examined and downloaded—in color—from our website. Our website also provides an electronic version of Maps 1 and 4—with links to the internet—so that readers can learn about the major scholars, topics, or fields of study in SACS and complexity science (See www.personal.kent.edu/~bcastel3/).

10.0 The Map

The most important visual technique in the SACS Toolkit is the *map*. Maps provide *global* snapshots of some aspect of a social system. They are not meant to visualize a social system in its entirety. Such a map would be, if not impossible, at least impractical. Maps are guides, not actual representations.

While global in focus, maps vary according to a list of dimensions—function, scale, detail, time-space, etc. For example, as the seven maps in this chapter demonstrate, while some maps (such as Map 1) provide a historical overview of a social system (in this case complexity science), others (such as Map 2) focus on a specific moment in time (i.e., the network of attracting clusters for SACS circa 2008).

One important difference we have noted in map function, which we wish to discuss here, is between maps created for the researcher versus

maps created for the reader. All seven maps provided in this chapter were originally created to help us, as the researchers, model the structure and dynamics of SACS and to help us understand its position within the larger systems of sociology and complexity science. Only when we wrote the book did they turn into maps intended for the reader.

For example, we initially created Map 1 as a way to visualize the history of complexity science, as it has developed over the last sixty years, including its intellectual lineages, major topics of study, and key historical figures. Map 1 proved very useful during the early stages of the modeling building phase because it allowed us to: (1) grasp the new field of complexity science, at the global level; (2) distinguish SACS, as its own field of study, from complexity science; and (3) determine where the five major areas of research in SACS are situated within the intellectual traditions, methods and topics of complexity science.

Map 2 is another example of a working map. In the middle stages of our research we had a difficult time dealing with the interstitial character of SACS, as well as the issue of whether SACS constituted the *sociology of something*—in this case, the sociology *of* complexity. We decided to create a map of SACS as an intellectual town. As we developed our map we realized that SACS really was not the *sociology of complexity*. Instead, given its interstitial character, it was better characterized as *sociology and complexity science*. Map 2 also provided us a metaphorical language (that of geography and archeology) that we used to outline sociology's historical relations with cybernetics and systems science, starting with Parsons and ending with SACS—See Chap. 4, specifically, Sect. 4.4.

Map 3 is our final example. This map (along with Figs. 1–3 and Flowcharts 1 and 2) visualizes the theoretical filing system used by the SACS Toolkit, providing a graphic checklist of all the things one needs to address when building a model of a social system. In fact, we found ourselves turning to Map 3 even during the final editing phase of our book, making sure we had a proper grasp of our model and that everything had been adequately addressed.

In summary, in terms of the SACS Toolkit, maps (along with their related figures and graphs) are an effective tool for modeling social systems. Given their utility (as well as our constant reliance upon them throughout this book) we placed all of our maps, figures and graphs here, in one chapter. This way the reader can refer to them as needed. For each map, figure and graph, we provide a brief description of how to read it, along with directions for where to go in the book for further study. In fact, we hope that Chap. 10 is reasonably self-sufficient that it can be read as a visual tour of our book.

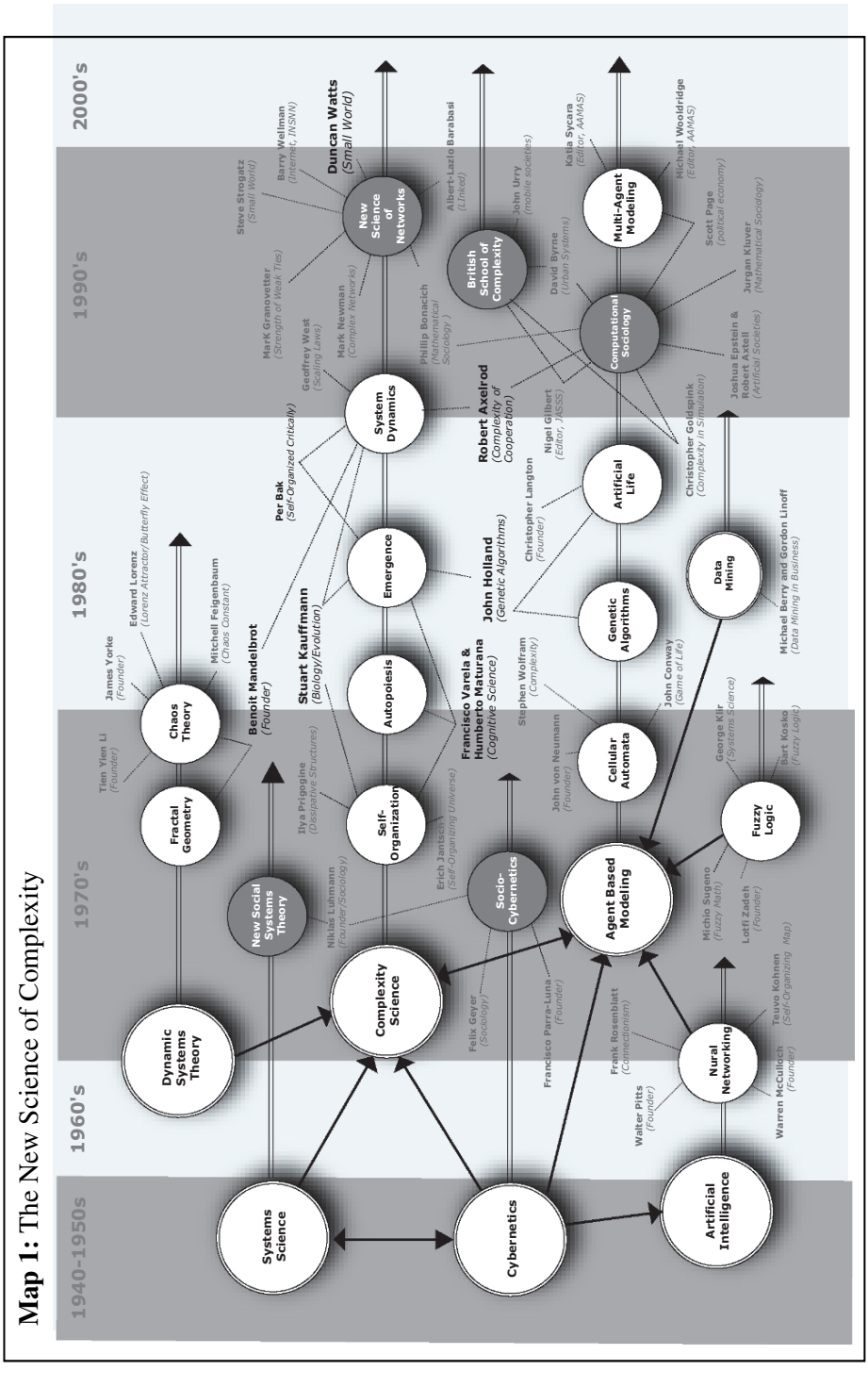
10.1 *Map 1: The New Science of Complexity*

Map 1 is a conceptual representation of complexity science and the five areas of research in SACS: computational sociology, complex social network analysis (CSNA), the Luhmann School of Complexity (LSC), sociocybernetics, and the British-based School of Complexity (BBC). All five areas of SACS are in grey.

Map 1 is to be read as follows: First, it is roughly historical, working as a timeline that is divided into five major periods, going from left to right: (1) old-school systems thinking, (2) the perturbation of complexity, (3) the new science of complexity, (4) progress, and (5) recent developments.

Because of the diversity of research in complexity science, Map 1 focuses on the key topics in the field that unite various substantive inquiries. These key topics are self-organization, emergence, autopoiesis, system dynamics and networks. Each field of study is represented as a double-lined ellipse, with a double-lined arrow moving from left to the right. The relative size of these ellipses is strictly a function of the space needed to write the name of each field. Double-lined arrows represent the trajectory of each field of study. Space constraints required that the length of these arrows be limited; readers should therefore assume that all of them extend outward to 2009. The decision where to place the various fields of research respective to one another is also somewhat arbitrary. However, we did try to position similar areas near each other. Areas of research identified for each field of study are represented as single-lined circles. The size of these circles is strictly a function of the space needed to write the different names. The intellectual links amongst the fields of study and areas of research are represented with a bold, single-lined arrow. The head of these single-lined arrows indicates the direction of the relationship. In some cases, the relationship is mutual.

For each area of research, we also include a short list of the leading scholars. This list is not exhaustive; but it is representative, based on number of citations, general recognition, and importance in the historical development of the area of research. For each scholar we provide the following information: name, most widely known contribution, and links to key areas of research. The links amongst the scholars and their respective areas of research are represented by a dashed line. One will also note that the names of the scholars differ in font size. This was done to demonstrate their relative importance within complexity science and the sociology of complexity.


Map 1: The New Science of Complexity
1940-1950s
1960's
1970's
1980's
1990's
2000's
Systems Science
Cybernetics
Artificial Intelligence
Dynamic Systems Theory
Complexity Science
Agent Based Modeling
New Social Systems Theory
Fractal Geometry
Chaos Theory
Self-Organization
Socio-Cybernetics
Nural Networking
Cellular Automata
Autopoiesis
Emergence
Genetic Algorithms
Fuzzy Logic
Data Mining
System Dynamics
Artificial Life
New Science of Networks
British School of Complexity
Computational Sociology
Multi-Agent Modeling
Benoit Mandelbrot (Founder)
Tien Yien Li (Founder)
James Yorke (Founder)
Edward Lorenz (Lorenz Attractor/Butterfly Effect)
Mitchell Feigenbaum (Chaos Constant)
Ilya Prigogine (Dissipative Structures)
Niklas Luhmann (Founder/Sociology)
Erich Jantsch (Self-Organizing Universe)
Felix Geyer (Sociology)
Francisco Parra-Luna (Founder)
Frank Rosenblatt (Connectionism)
Walter Pitts (Founder)
Warren McCulloch (Founder)
Teuvo Kohnen (Self-Organizing Map)
Michio Sugeno (Fuzzy Math)
Lotfi Zadeh (Founder)
Francisco Varela & Humberto Maturana (Cognitive Science)
John von Neumann (Founder)
Stephen Wolfram (Complexity)
John Conway (Game of Life)
George Klir (Systems Science)
Bart Kosko (Fuzzy Logic)
Stuart Kauffmann (Biology/Evolution)
Per Bak (Self-Organized Criticality)
John Holland (Genetic Algorithms)
Michael Berry and Gordon Linoff (Data Mining in Business)
Christopher Langton (Founder)
Christopher Goldspink (Complexity in Simulation)
Robert Axelrod (Complexity of Cooperation)
Nigel Gilbert (Editor, JASSS)
Geoffrey West (Scaling Laws)
Mark Newman (Complex Networks)
Mark Granovetter (Strength of Weak Ties)
Steve Strogatz (Small World)
Barry Wellman (Internet, INSNA)
Duncan Watts (Small World)
Philip Bonacich (Mathematical Sociology)
Albert-Laszlo Barabasi (Linked)
John Urry (mobile societies)
David Byrne (Urban Systems)
Joshua Epstein & Robert Axtell (Artificial Societies)
Jurgan Kluver (Mathematical Sociology)
Scott Page (political economy)
Katia Sycara (Editor, AAMAS)
Michael Wooldridge (Editor, AAMAS)

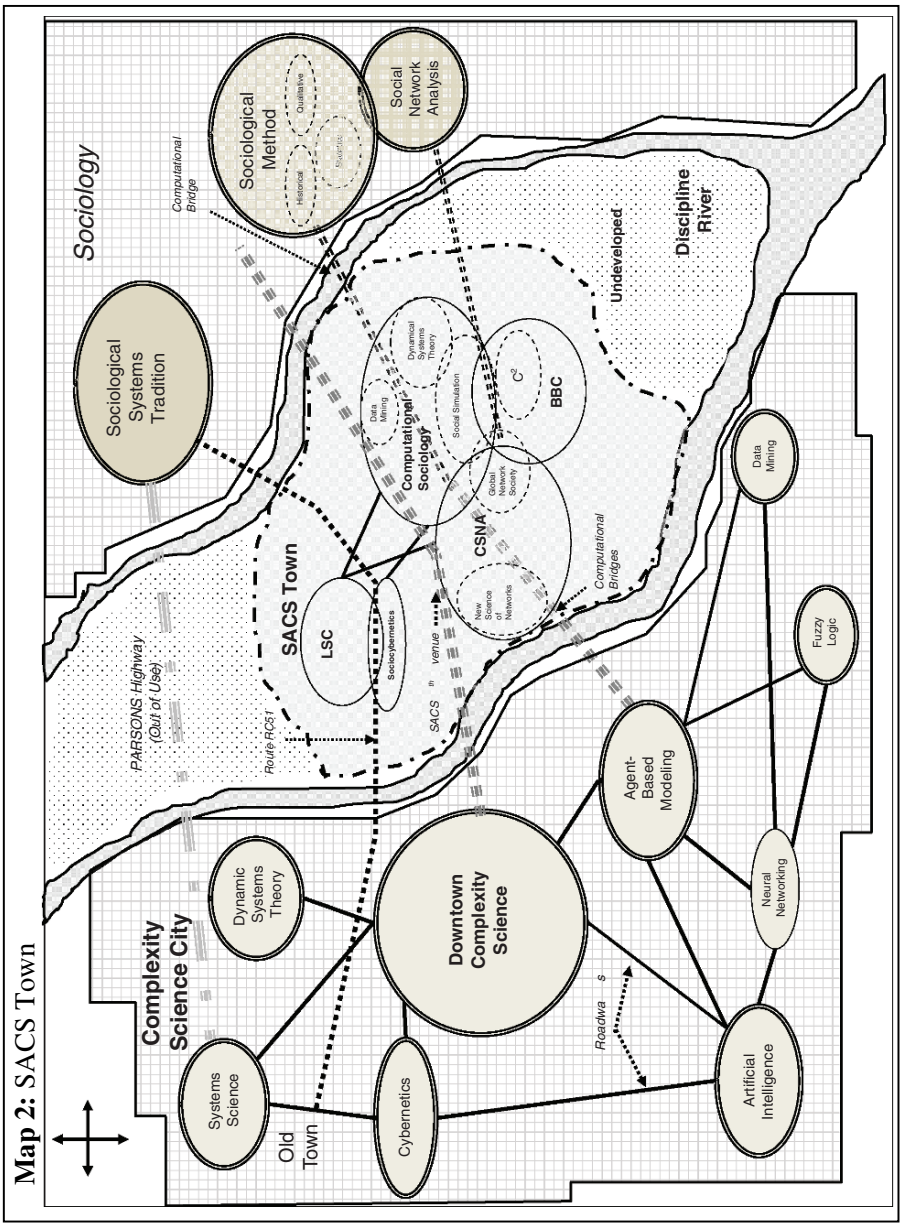
10.2 *Map 2: SACS Town*

Map 2 visualizes SACS in geographical and archeological terms. In terms of geography, our goal is to position SACS (metaphorically speaking) relative to the two largest intellectual systems of which it is a part, namely complexity science and sociology. In terms of archeology, our goal is to position SACS and its five areas of research relative to the functionalist phase of the systems tradition in sociology.

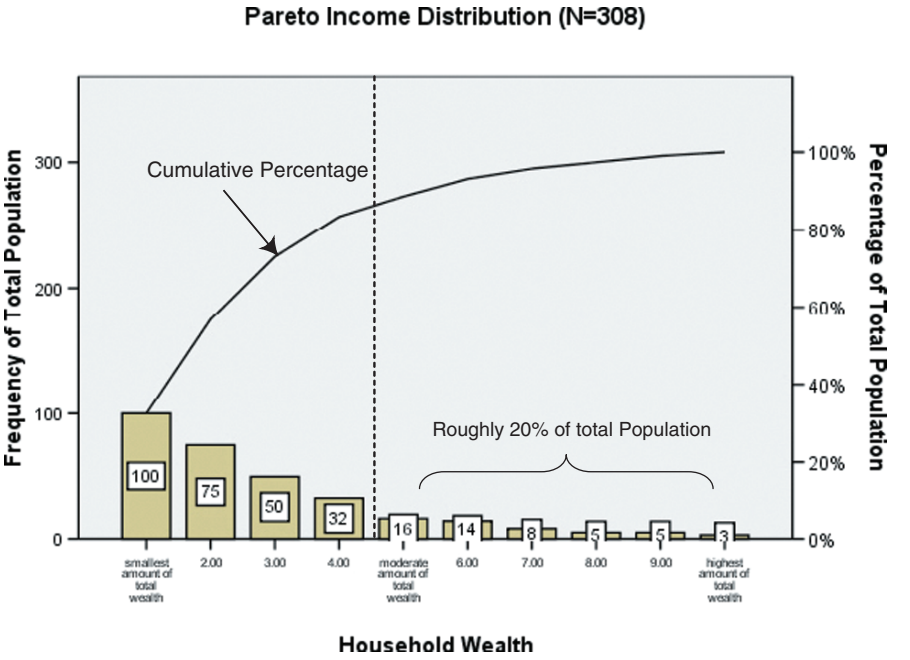
The Geography of SACS: Map 2 is to be read like a typical road map, wherein disciplines, fields of study and schools of thought are treated as states, cities, towns and communities; and wherein the positioning of these various municipalities are thought of in geographical (spatial) terms and the connections (links) between these various municipalities are thought of in terms of roads, highways and so forth. The division between these intellectual systems is also taken into account in the form of spatial dividers such as rivers, forks, and boundary lines.

For example, sociology is treated as a state, while the natural sciences are conceptualized as a country. Complexity science is viewed as a city and SACS is treated as a town. For more information on the geography of Map 2, see Chap. 1, Sect. 1.3. See also Chap. 4, in particular 4.4. Like Map 1, circle size in Map 2 is strictly a function of the space needed to write the name of each field, with one noted exception. Because the sub-clusters of research are subsumed under their respective areas of research, they are purposely smaller in size. For example, Global Network Society is a sub-cluster of research within Complex Social Network Analysis (CSNA) and so it is smaller.

The Archeology of SACS: In Chap. 4 we spend time discussing the links between the functionalist phase of the systems tradition in sociology and its current complexity phase, which has to do with SACS. Map 2 provides a way to conceptualize this relationship by visualizing the archeological ruins of functionalism, including such things as old Parsons Highway. While metaphorical, we found Map 2 very helpful in our own model building process and in our explanations of the history of SACS. For more information, see Chaps. 4 and 7, in particular, Sect. 7.2.

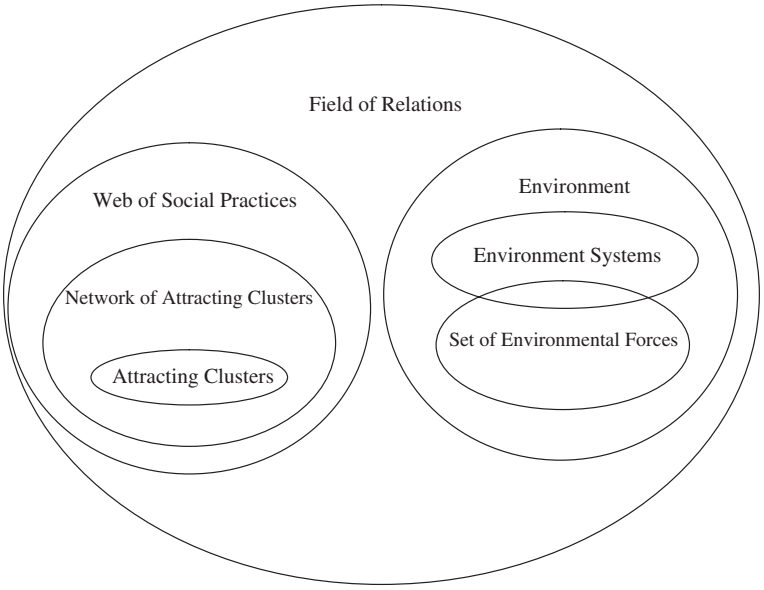

Map 2: SACS Town
Complexity Science City
Old Town
Systems Science
Dynamic Systems Theory
Cybernetics
Downtown Complexity Science
Roadway
Agent-Based Modeling
Artificial Intelligence
Neural Networking
Fuzzy Logic
Data Mining
Undeveloped
Discipline River
Sociology
Sociological Systems Tradition
Computational Bridge
Sociological Method
Qualitative
Historical
Social Network Analysis
PARSONS Highway (Out of Use)
Route RC81
SACS Town
LSC
Society/Kemetics
SACS th venue
Computational Sociology
Data Mining
Dynamical Systems Theory
Social Simulation
CSNA
Global Network Society
New Science of Networks
BBC
C3
Computational Bridges

10.3 *Graph 1: The Pareto Distribution*



This Graph is an example of the classic Pareto Distribution wherein the top 20% of households own roughly 80% of the total wealth in a given population. For more information on this graph, see Chap. 1, Sect. 1.2.3.1

10.4 *Figure 1: Venn Diagram of SACS Folders*



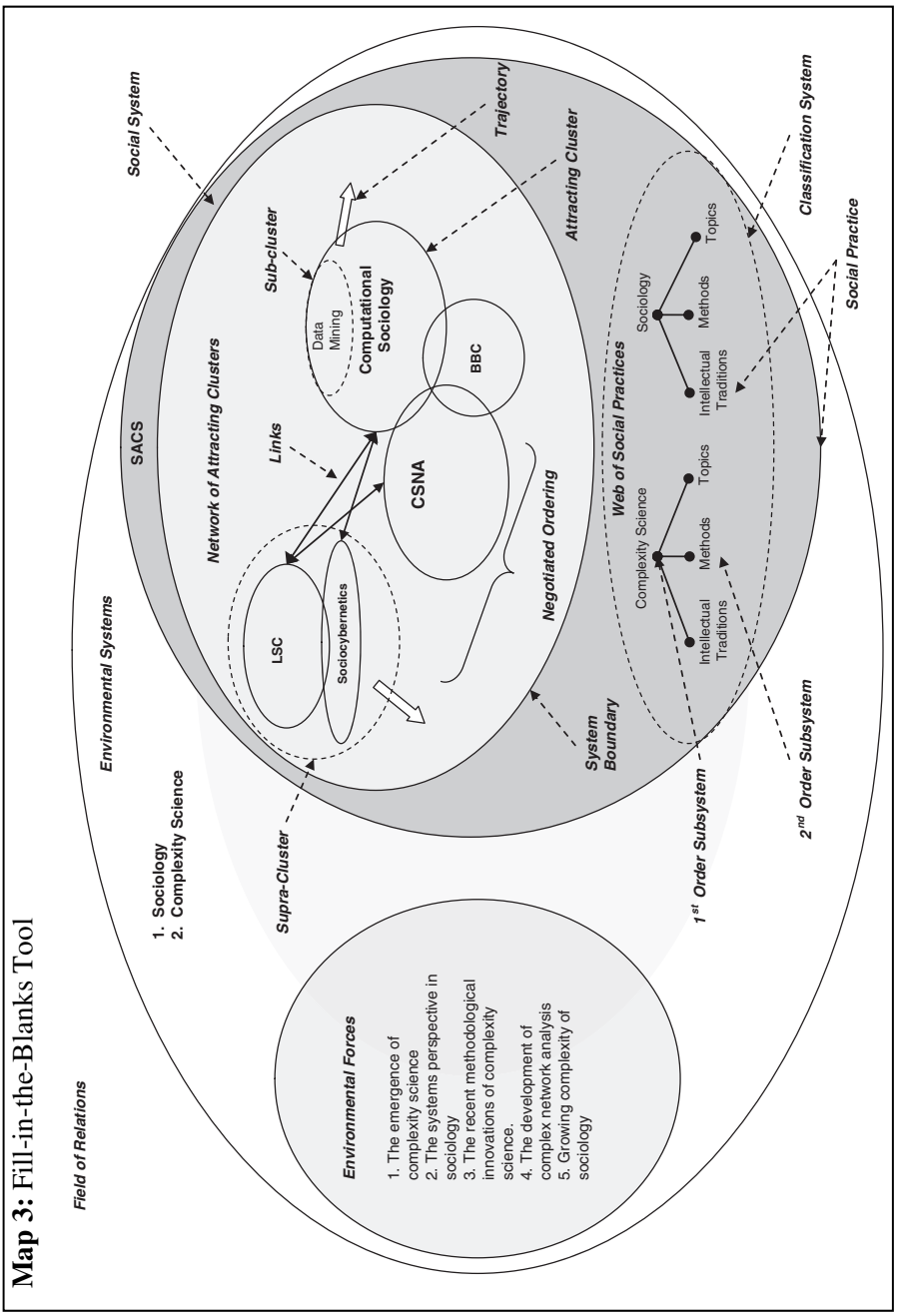
This Venn diagram visualizes the folders (as subsets) used by social complexity theory—the theoretical framework of the SACS Toolkit—to organize an investigation into a social system. For more information on this diagram, see Chap. 2, Sect. 2.2.5.

10.5 *Map 3: Fill-in-the-Blanks Tool*

Map 3 is a visual aide used by the researcher during the model building process. It works as a fill-in-the-blanks picture. As the model is built, the researcher fills in the various areas of the map. Each area corresponds to one of the conceptual folders from the SACS Toolkit—environmental systems, web of social practices, network of attracting clusters, etc. The researcher also uses the map to ensure that all of the major terms in the SACS Toolkit are used appropriately, such as negotiated ordering, trajectory, sub-cluster and so forth.

The particular model shown in Map 3 is SACS, circa 2008. In Map 3 are found the key environmental systems and forces impacting SACS, as well as a brief overview of the web of social practices and the network of attracting clusters for SACS. For a complete rendering of the web of social practices, see Fig. 2. For a complete picture of the network of attracting clusters, see Map 4. Also, for a visualization of the assemblage algorithm, which is used to create Map 3, see Flowcharts 1 and 2.

Once filled in, or during the process of creating Map 3, the researcher gains a quick overview of the model. The researcher can also use Map 3 to assist visually such questions as: Is my model working? Can I explain my model to a colleague or myself and it makes sense? Is my model holding together well? Am I arriving at some new insights? Do my attracting clusters make sense? Are they positioned correctly in relation to one another? Have I accounted for all of the necessary environmental forces? And so forth. For more information on Map 3, see Chap. 2.


Map 3: Fill-in-the-Blanks Tool
Field of Relations
Environmental Systems
Social System
1. Sociology
2. Complexity Science
Environmental Forces
1. The emergence of complexity science
2. The systems perspective in sociology
3. The recent methodological innovations of complexity science.
4. The development of complex network analysis
5. Growing complexity of sociology
Supra-Cluster
SACS
Network of Attracting Clusters
Links
Sub-cluster
Trajectory
Attracting Cluster
LSC
Sociocybernetics
CSNA
Data Mining
Computational Sociology
BBC
Negotiated Ordering
System Boundary
Web of Social Practices
Complexity Science
Intellectual Traditions
Methods
Topics
Sociology
Intellectual Traditions
Methods
Topics
1st Order Subsystem
2nd Order Subsystem
Classification System
Social Practice

10.6 *Figure 2: Web of Social Practices for SACS*

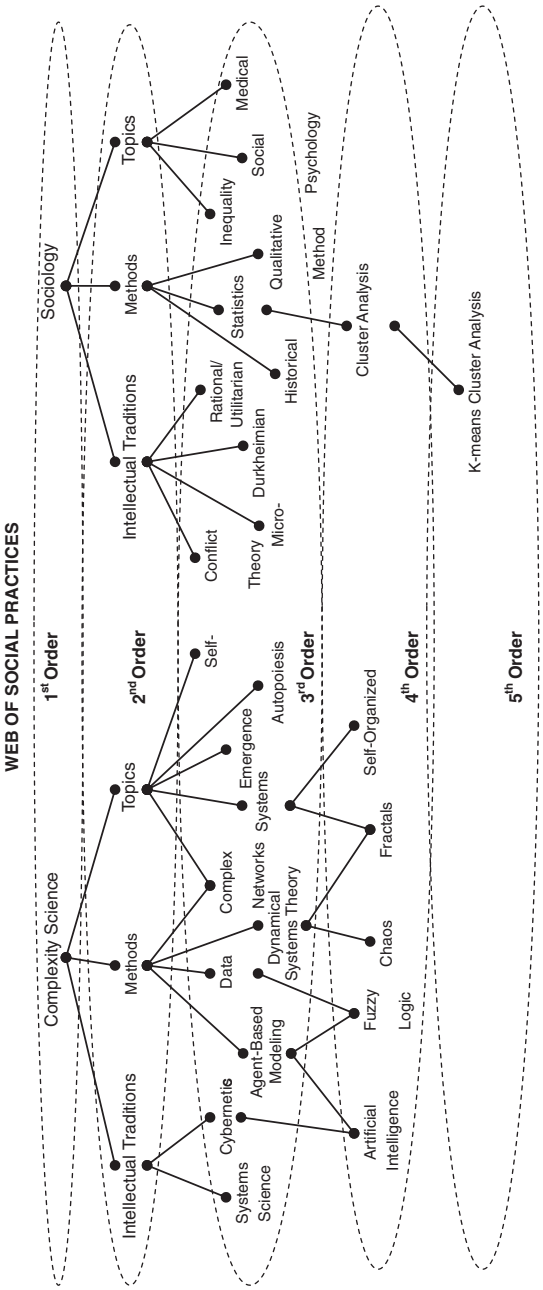


Figure 2 shows the web of social practices for SACS. Like a root structure, the web of social practices is organized into a series of successive (nth order) layers, each of which is subsumed under the social practices found in the preceding layer. For example, under the first-order social

practice, sociology, are the second order sub-practices of intellectual traditions, methods and topics. Moving to the third-order, within methods, for example there are the sub-practices of historical, statistical and qualitative method. One can continue this layering ad infinitum, depending upon the level of detail needed for one's model. For more information on the web of social practices and its usage in our study of SACS, see Chap. 2, Sect. 2.2.6.

10.7 *Figure 3: Web of Social Practices as Molecule*

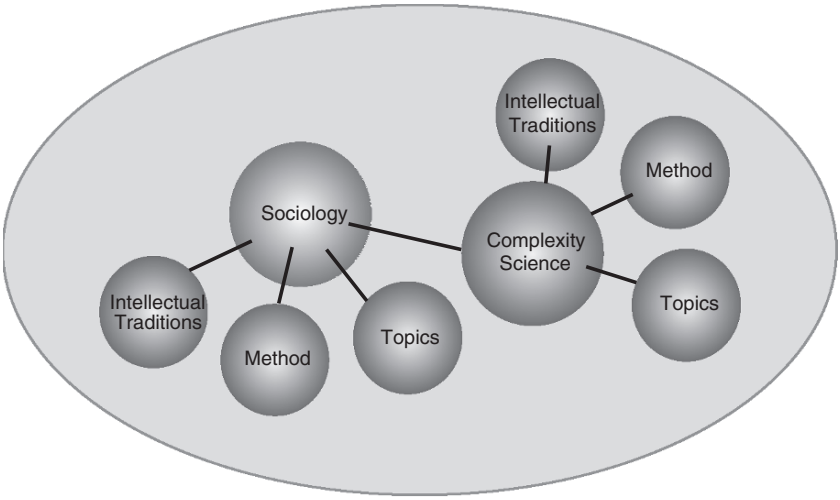


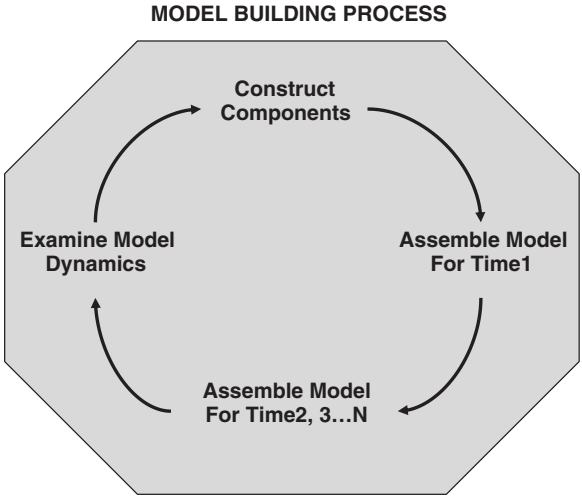
Figure 3 shows the web of social practices for SACS as a molecule. This figured is used to demonstrate our concept of coupling. For more information see Chap. 2, Sect. 2.2.7.1

10.8 *Flowcharts 1 and 2*

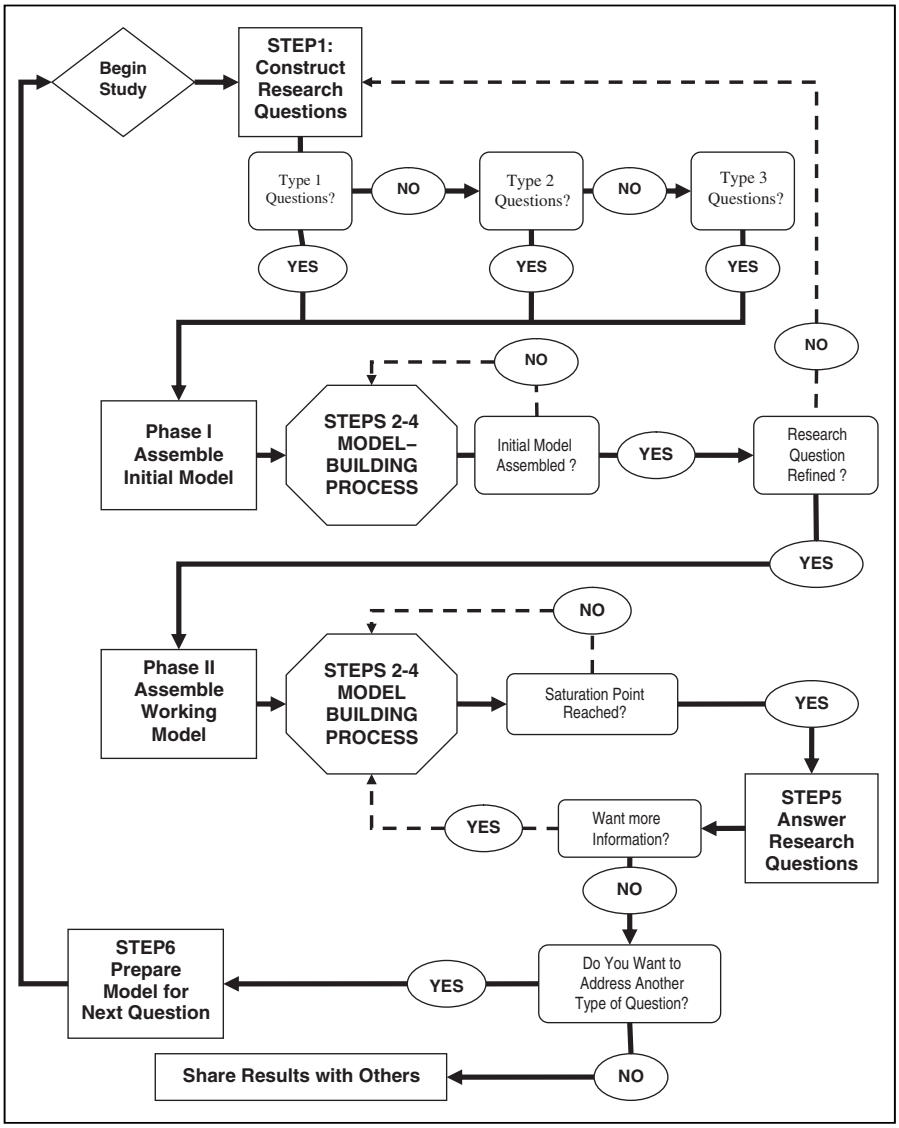
Flowcharts 1 and 2 visualize the assemblage algorithm used by the SACS Toolkit to construct a model of a social system from the ground-up. *Assemblage* is a case-based, system-clustering algorithm for modeling social systems. It is built on the organizational framework of social complexity theory and represents the procedural component of the SACS Toolkit.

As shown in flowchart 1, the goal of assemblage is to move researchers through a six-step algorithm for constructing a model of some social system of study. This algorithm roughly proceeds as follows: (1) help the researcher define a set of research questions in systems terms; (2) establish the social system's field of relations and determine the web of social practices out of which it emerges; (3) use this information to catalogue the numerous ways the system is coupled/expressed at a particular moment in time-space; (4) condense/cluster this catalogue into a smaller grid of the system's most important practices to create the network of attracting clusters; (5) examine the internal dynamics of this network for a particular moment in time-space, including its interactions with key environmental forces and its trajectory within key environmental systems; and, finally (6) assemble these discrete, cross-sectional snapshots of the system into a moving model, concluding this some overall sense of the system as a whole. Once done, researchers can "data mine" this model to answer the initial study questions or to generate new questions or models. Flowchart 2 provides a detailed overview of the core of the model building process—Steps 2 through 4.

Flowchart 2: The Core Steps, 2 Through 4



Flowchart 1: The Assemblage Algorithm



10.9 *Map 4: The Community of SACS*

Map 8 depicts the network of attracting clusters for SACS. It was created based on our historical study of SACS circa 2008.

Each oval on this map represents one of the major ways that SACS is practiced; that is, one of the major ways that the intellectual traditions, methods, and topics of sociology and complexity science tend to couple. Together, these ovals represent the five major research communities in SACS at a particular moment in time-space; specifically SACS in Europe and North America between 2006 and 2008—computational sociology, sociocybernetics, the Luhmann School of Complexity (LSC), complex social network analysis (CSNA), and the British-based School of Complexity (BBC).

In the language of fractal geometry, each oval in Map 4 is an attractor point around which a more exhaustive list of smaller couplings (in this case, scholars and subfields of research) gathers. Said another way, the scholars listed in Map 4 are empirical expressions of the numerous "couplings" taking place within and between the five research communities of SACS. In other words, the scholars listed on Map 4 are not just people; they are expressions of the coupling of social practice.

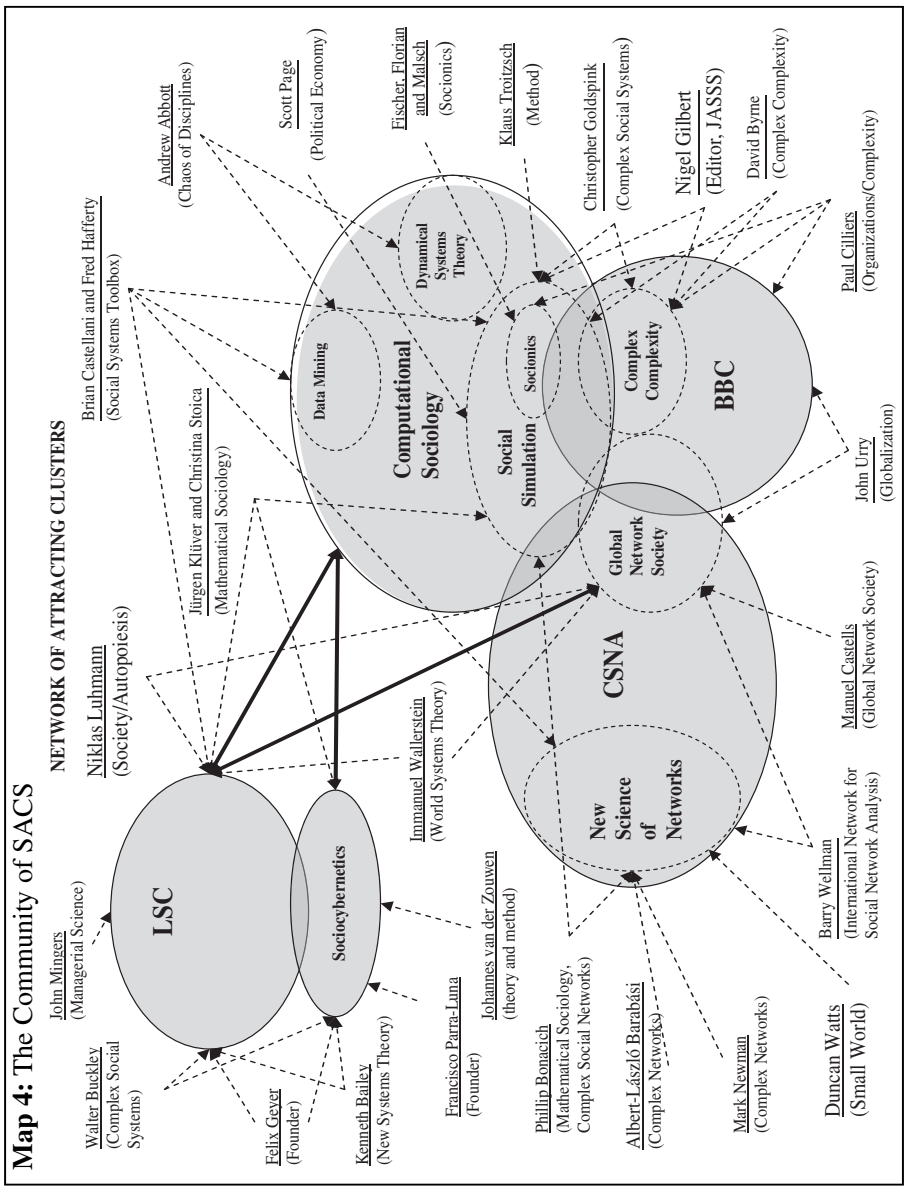
The dotted arrows show the primary areas of research to which the scholars on Map 4 are linked.

Below each scholar's name, in parentheses, is the area of work for which the scholar in most known. As in Map 1, the larger the font for a scholar, the more important the scholar is to SACS—see Chap. 7, Sect. 7.1.4 for our definition of scholarly importance, which has to do with hubs, authorities, gatekeepers and household names.

The dotted ovals within the five areas of research are the sub-clusters of study within SACS. Some of these sub-clusters overlap with more than one area of research, as in the case of global network society.

The solid arrows show which areas of research and sub-clusters in SACS have the strongest relationships with one another.

The closer an area of research is to the center of Map 4, or the larger an area of research is, the more important it is to the last decade of development in SACS (1998–2008). For our definition of importance, see Chap. 7.

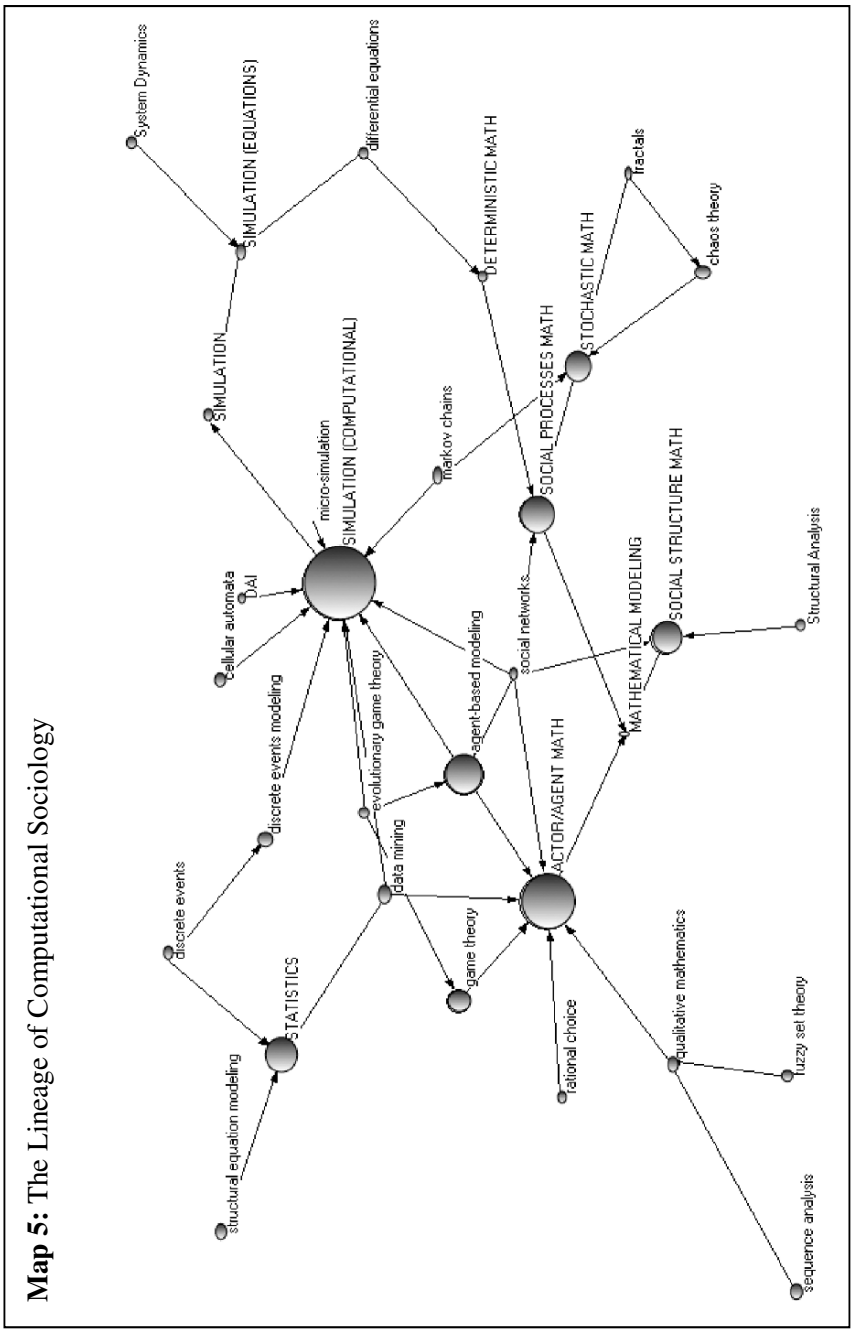

Map 4: The Community of SACS
NETWORK OF ATTRACTING CLUSTERS
LSC
Sociocybernetics
CSNA
New Science of Networks
Global Network Society
Computational Sociology
Data Mining
Social Simulation
Sociomics
Dynamical Systems Theory
Complex Complexity
BBC
John Mingers (Managerial Science)
Walter Buckley (Complex Social Systems)
Felix Geyer (Founder)
Kenneth Bailey (New Systems Theory)
Niklas Luhmann (Society/Autopoiesis)
Brian Castellani and Fred Hafferty (Social Systems Toolbox)
Jürgen Klüver and Christina Stoica (Mathematical Sociology)
Immanuel Wallerstein (World Systems Theory)
Francisco Parra-Luna (Founder)
Johannes van der Zouwen (theory and method)
Phillip Bonacich (Mathematical Sociology, Complex Social Networks)
Albert-László Barabási (Complex Networks)
Mark Newman (Complex Networks)
Duncan Watts (Small World)
Barry Wellman (International Network for Social Network Analysis)
Manuel Castells (Global Network Society)
John Urry (Globalization)
Paul Cilliers (Organizations/Complexity)
Andrew Abbott (Chaos of Disciplines)
Scott Page (Political Economy)
Fischer, Florian and Malsch (Sociomics)
Klaus Troitzsch (Method)
Christopher Goldspink (Complex Social Systems)
Nigel Gilbert (Editor, JASSS)
David Byrne (Complex Complexity)

10.10 *Map 5: The Lineage of Computational Sociology*

Map 5 was created in the network software package called Pajek (Nooy, Mrvar and Batagelj 2005). It provides a genealogical tree of the impact the various areas in mathematics have on computational sociology, including statistics, computer simulation (specifically agent-based modeling) and formal mathematical modeling (specifically, discrete mathematics, stochastic processes and dynamical systems theory).

Map 5 was also created to visually demonstrate which areas of modern mathematics have had the biggest influence on computational sociology. The larger the circle (node) is in Map 5; the bigger its impact on the work being done in computational sociology today.

For a detailed review of how we created Map 5, including how we defined "impact," see Chap. 6, Sect. 6.1. *Complexity Science and Sociological Method.*



Map 5: The Lineage of Computational Sociology

10.11 *Map 6: Social Network Model of SACS*

Maps 6 and 7 wer created in the network software package called Pajek (Nooy, Mrvar and Batagelj 2005). Map 6 is a social network model of SACS based on the published links amongst the Top 25 Scholars in SACS. The database for this model came from the Web of Science Citation Index. See Map 6 Notes for details. See also Chap. 7, Sect. 7.1.5 and Sect. 7.1.6.

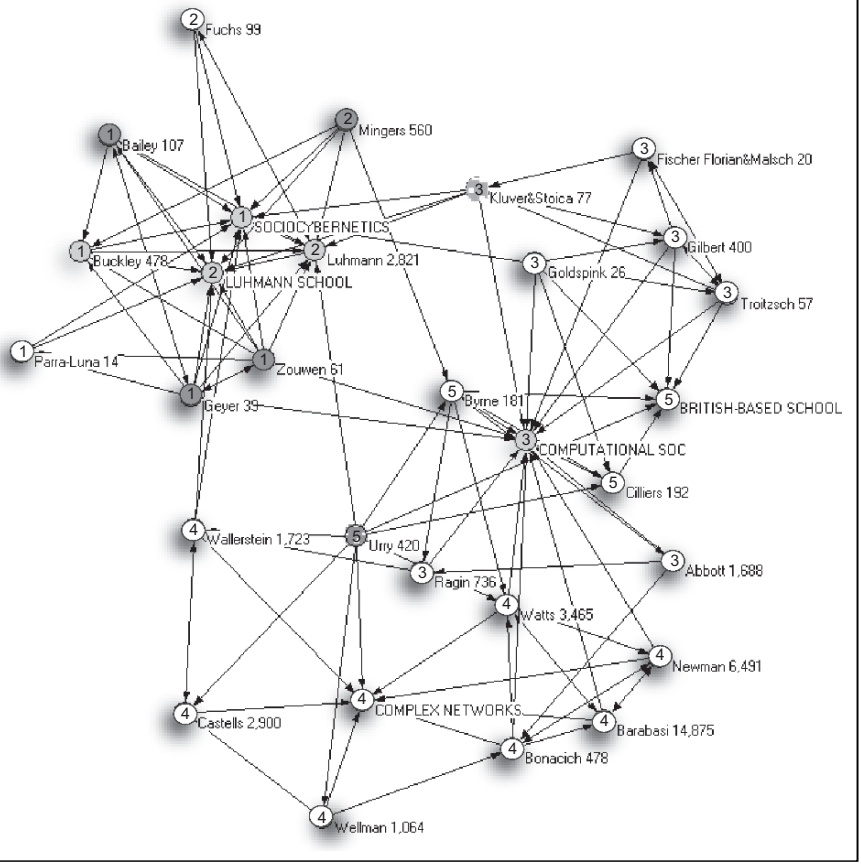
Reading Map 6

In terms of reading Map 6, the numbers in the circles represent the area of research to which the Top 25 Scholars belong. In Pajek, these areas of research are referred to as partitions: 1 = Sociocybernetics; 2 = Luhmann School (short for Luhmann School of Complexity); 3 = Computational Soc (short for computational sociology); 4 = Complex Networks (short for complex social network analysis); and 5 = British-based School (short for the British-based School of Complexity). The five areas of research are in UPPERCASE to distinguish them from the scholar nodes.

The color of the circles refers to the type of powerbroker the node is within the network of Top 25 Scholars: gatekeepers, authorities and hubs. Regular nodes are white; Gatekeepers are checkered; authorities are dark grey and hubs are light grey. Household names (the fourth type of powerbroker) are indicated by the total citations for a Top 25 Scholar—this is the number located next to the name of each Top 25 Scholar. Wallerstein, for example, has been cited 1,723 time; whereas Goldspink has been cited a total of 26 times.

As a final note, the direction of the arrows run from the citing scholar to the scholar being cited. Wellman, for example, cites Bonacich. If the arrow runs both ways, each author cites the other. Newman and Watts, for example, cite each other.

Map 6: Social Network Model of SACS



10.12 *Map 7: Social Network Map of SACS Minus Gatekeepers*

Map 7 is the same model as Map 6 and is read exactly the same way. The only difference is that Map 7 does not highlight the hubs, authorities, household names or gatekeepers in SACS. Instead, it shows what the SACS community looks like if the two gatekeepers amongst its Top 25 Scholars were removed. For more information on Map 7 and the concept of gatekeeper, see Chap. 8, Sect. 8.0.4.3.